Wheelchair propulsion: a straining form of ambulation

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Commentary

Wheelchair propulsion: a straining form of ambulation

Manual wheelchair propulsion is a straining form of ambulation, both for the cardio-respiratory as well as the musculo-skeletal system. Wheelchair locomotion implies arm work in every other activity in daily life. Compared to leg work, wheelchair arm work is much less efficient and more straining, and subsequently leads to a lower work capacity[1,2]. Underlying pathology may further influence performance capacity, as is illustrated by Mukherjee *et al*[3] in the comparison of wheelchair dependent subjects with non-wheelchair users in this issue. In addition, hand rim wheelchair propulsion - the most common form of manual wheelchair ambulation in the western world - is overall a very inefficient mode of exercise due to the coupling/decoupling of the hand to the rim, the execution of the movement partly outside the visual field[2]. In hand rim wheelchair locomotion task load and physical work capacity therefore often seem out-off balance.

Problems of long-term wheelchair use described in literature are not just discomfort, but (chronic) pain and even structural musculo-skeletal damage[4,5] with the subsequent risk of increasing inactivity. As a consequence, serious secondary impairments (obesity, diabetes, cardiovascular problems) may eventually emerge[6]. Improved wheelchair quality, including a more optimal propulsion mechanism and the ergonomic fitting to the individual, as well as improved propulsion technique and overall work capacity, play an important preventive role here. Above that, it will contribute to the freedom of mobility and participation.

The context of wheelchair research: Apart from empirical developments, often stimulated from within wheelchair sports, biomechanical and physiological research have played a role over the years in understanding upper-body wheelchair work in three important areas[2]: (*i*) the vehicle mechanics; (*ii*) the human movement system; and (*iii*) the wheelchair-user interface.

The current and previous work of Mukherjee and colleagues[3,7-11] indirectly exemplify the importance of experimental and descriptive research with respect to aspects of both work capacity and the wheelchair-user interface.

To date, the majority of wheelchair research stems from research groups based in western countries and obviously is directed towards populations of users and wheelchairs in predominantly western countries and their environment. As such, apart from the work of Mukherjee *et al*[3] and Goswami *et al*[12], little research is available that addresses specific non-western populations of users or wheelchairs. Indeed, next to the environmental conditions of use (in non-western countries climatologic and physical conditions are assumed to often require higher levels of external power output), there will be important differences in physiology and anthropometry among user populations, as well as among populations of wheelchairs studied and used. The application of absolute physiological, anthropometrical or biomechanical (norm) data - but not the overall and relative trends in the material - from wheelchair research originating from studies in western countries will therefore be limited for the specific Indian environmental context as well as for their user populations and specific wheelchairs used. This stresses at least part of the importance of the work of Mukherjee *et al*[3].

Large number studies: The relatively large numbers in the experimental study of Mukherjee *et al*[3] is another important asset of this work. Experimental work around the wheelchair-user interface - which is indirectly one of the interesting aspects of the study - is commonly portrayed on small - often able-bodied - subject groups[13]. This obviously limits the generalizibility of the results. Subpopulations in the study of Mukherjee *et al*[3] range between 17 and 77 subjects, whereas the overall number of subjects adds up to 174, which strengthens the message of the paper.

What is remarkable though in the population studied, is the absence of the 50-60 yr age bracket, since one of the research questions is the effect of age on wheelchair performance. This age group is an important user group in (studies from) western countries, especially in the light of age-effects. Demographic influences will obviously have had an impact here, again stressing the importance of population specific data on work capacity and physical strain, also in the rehabilitation context.

Physical strain and work capacity: Physical strain of wheelchair propulsion, both metabolic and mechanical, is generally judged to be high[1-14]. A high physical strain will impact the common daily use of a wheelchair and thus the overall work capacity of an individual, albeit positive or negative. The latter depends on the daily amount of physical activity or activity behaviour (apart from labour and sports related activities) and may be different in the population studied by Mukherjee *et al*[3], as compared to studies available in literature[1,14,15] that were primarily conducted in western countries. In the latter countries, motorized mobility - and thus an inactive lifestyle - is possibly much more common.

The study clearly illustrates that physical work capacity in the different wheelchair populations was not significantly different. The fact that the able-bodied subject group proved to have a higher work capacity than any of the other wheelchair user groups seems self-evident. Firstly, as a consequence of a seated life, wheelchair users will in general be less fit than a matched able-bodied group. In able-bodied persons larger leg and trunk muscle groups are activated during daily activities, generating a larger impulse to the cardiorespiratory system than can be expected from arm work only. Secondly, arm crank exercise as a specific testing mode may have allowed the influence of the activation of the legs and trunk in the able-bodied subject group when possible. Leg and trunk muscles can and will be used to stabilize the body and to add to the power generating muscle mass.

On the other hand, since the wheelchair subject groups are rather comparable in disability, gender, age and obviously their physical activity lifestyle, no differences may be expected in peak oxygen uptake capacity and peak heart rate among these groups, since they were all tested on the same arm crank ergometer. This is a non-specific form of upper-body exercise, simple to learn and to perform. Wheelchair mode (and the effect of daily practice and learning with the mode: hand rim, lever, crank) clearly does not necessarily impact peak oxygen uptake or peak heart rate, since the same and equally trained muscle mass is used. However, daily propulsion mode may impact the ability to generate external power[16]. Peak external power output is not only dependent on peak oxygen uptake but also on mechanical efficiency[2]. Those using bimanual arm crank propulsion in daily life may be more efficient, than the other (*i.e.*, hand rim or lever) wheelchair users, thus allowing the production of a higher external power output (Watt) at a similar peak oxygen uptake. Unfortunately, although external power output was known, it was not presented in this paper[3]. Power output must be viewed as a very important outcome measure of peak physical work capacity in wheelchair research, since it is sensitive to changes in propulsion mode and gross mechanical efficiency[16-18]. Power output during arm crank exercise testing can indeed easily be measured and must be presented as such in wheelchair exercise studies as an additional outcome measure. In hand rim wheelchair propulsion it is more difficult to obtain, since it requires specific ergometry or force measuring tools[2].

Alternative propulsion modes: Over the years, both in sports practice and research, focus has shifted towards alternative modes of manual propulsion, especially cranks. Research into the 'why', 'how' and 'if' questions has only just begun and will have to further substantiate the underlying mechanisms and processes in upper body work, as well as the high expectations of practical applications, both in daily practice as well as in rehabilitation[16-18]. Arm crank propulsion-based wheelchairs are becoming increasingly popular in western countries, because they allow a higher velocity, at a lower metabolic cost and over a longer distance, even in those with considerable functional limitations[13,16-20]. The design of the tricycles in the latter studies will be different from those studied in Mukherjee *et al*[3]. However, the beneficial principles will be more or less similar, *i.e.*, a larger muscle volume and diversity of muscles, a more natural hand-coupling and a continuous force generation involved in hand cycling.

Overuse: One of the important expectations of alternative modes of wheelchair propulsion, especially hand cycles or lever-based systems, is that they will lead to a lower incidence of musculo-skeletal overuse problems. Overuse problems in the upper extremities are a major secondary health problem in long-term hand rim wheelchair use[4,5,21]. Evidently, Mukherjee *et al*[3] have focussed on the metabolic consequences of chronic use of different propulsion mechanisms. A follow-up study into the issue of upper extremity discomfort, pain or structural damage in association to the daily wheelchair configuration would clearly help the further understanding of wheelchair arm work in relation to overuse problems. Especially, the relationship with propulsion mechanism could be focussed upon. Indian wheelchair users will necessarily use only one of the propulsion modes described by Mukherjee *et al*[3], while the wheelchair user in western countries will generally use a hand rim wheelchair with or without an outdoor hand cycle.

Conclusion

The importance of the work is in the specific population of users and of wheelchairs at study which indeed should be continued.

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